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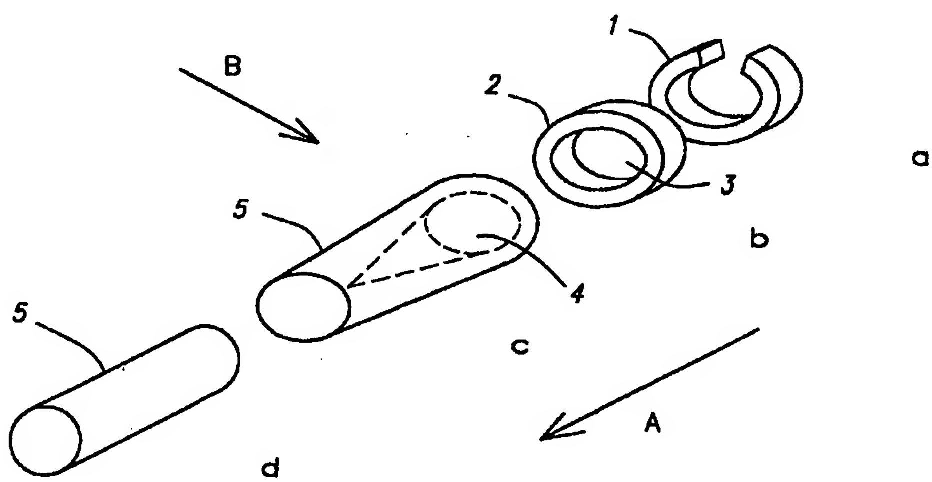

(57) Abstract

A spinneret plate is described with a plurality of apertures through which a molten thermoplastic material may be extruded for the production of self-crimping thermoplastic filaments. On the face of the spinneret plate against which the molten thermoplastic material is urged in the extrusion process, the apertures (1) have a shape with an incomplete periphery, such as a "C" shape or swastika shape, and the shape of the apertures (2) on the face of the spinneret plate at which the extruded material reports is of complete periphery, for example circular or square apertures. The entrainment of air as the thermoplastic material is extruded creates a void (4) internally of the filament which collapses as said material reports from the apertures of the spinneret plate and is immediately cooled. This causes the fibres to self-crimp which is of great advantage – current machinery to induce crimp is expensive and cumbersome.

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CRIMPED SOLID THERMOPLASTIC FILAMENTS

The present invention relates to an apparatus and method for producing crimped solid thermoplastic filaments and relates particularly, but not exclusively, to such an apparatus and method for producing polypropylene fibres and filaments.

One of the uses of crimped thermoplastic filaments is in the manufacture of products requiring a large number of filaments possessing a certain degree of resilience, for example in the manufacture of fibres for carpets or floor coverings. Whilst the use of polypropylene for the production of such fibres would generally be desirable because of its low cost, it has hitherto been difficult, if not impossible, to produce polypropylene fibres having the desired degree of resilience in comparison with the resiliency of wool or nylon.

Preferred embodiments of the present invention seek to provide an apparatus and method for producing crimped solid thermoplastic filaments having a satisfactory degree of crimp, and a higher degree of resilience. Preferred embodiments also seek to provide such an apparatus and method applicable to the production of polypropylene fibres.

According to an aspect of the present invention, there is provided a spinneret plate for use in producing crimped solid thermoplastic filaments, the spinneret plate comprising a plurality of apertures therethrough, wherein each said aperture comprises:

a first portion having a first transverse cross section defining a discontinuous loop, wherein the loop substantially surrounds a solid portion of the spinneret plate; and

a second portion having a second transverse cross section defining a continuous loop corresponding substantially to the discontinuous loop of said first portion,

wherein molten thermoplastic material is passed in use through the apertures in a direction from the first portions to the second portions.

The exact mechanism by which the crimped thermoplastic

filaments are formed is not yet fully understood. However, it is believed that the thermoplastic material flowing from the first portion to the second portion of each aperture forms a "torus" of molten thermoplastic material as it enters the second portion. This is believed to prevent the external air from entering into the interior of the tubular filament formed and which would otherwise support a hollow filament. It is believed that the external atmospheric pressure subsequently causes the tubular filament to collapse to form a solid filament and subsequent non-uniform transverse cooling of the filament produces a greater degree of crimp than in the prior art.

In one preferred embodiment, each said first portion has a substantially C-shaped cross section.

In another preferred embodiment, each said first portion has a substantially S-shaped cross section.

In a further preferred embodiment, each said first portion has a substantially swastika-shaped cross section.

By providing a first portion having a greater number of discontinuities than a C-shape, this enables a filament to be formed which on leaving the spinneret plate has more than one void enclosed therein. This is believed to provide the advantage of enabling the transverse cooling effect to be enhanced.

According to another aspect of the invention, there is provided an apparatus for producing crimped solid thermoplastic filaments, the apparatus comprising:

feeding means for feeding molten thermoplastic material to a spinneret plate as defined above so as to pass through said apertures in a direction from said first portions to said second portions thereby forming fibres; and

cooling means for non-uniform cooling of the fibres in a direction transverse to the drawing direction.

Preferably, the cooling means comprise air blowing means for blowing air onto the filaments from one side thereof.

According to a further aspect of the invention, there is provided a method of producing crimped solid thermoplastic

filaments, the method comprising:

passing molten thermoplastic material through a spinneret plate as defined above thereby forming filaments; and

cooling said filaments in a non-uniform manner in a direction transverse to the drawing direction.

Preferably, the method is a method for producing polypropylene fibres.

Advantageously, the method further comprises the step of passing the cooled filaments over a spin finish application roller.

This results in the fibres being coated with an anti-static solution to aid the further processing of the fibre without undue generation of static electricity in the fibres.

Conveniently, the method further comprises the step of passing the fibres through heating means.

This results in heat treatment of the fibres in a way which does not subject them to any undue tension and does not create any molecular orientation of the fibres.

The heating means may be an oven or alternatively may be heated rollers.

Preferably, the method further comprises stretching the heat treated fibres;

heating the stretched fibres;

tensioning the fibres;

cutting the fibres into individual short lengths of fibre.

As an aid to understanding the invention, preferred embodiments thereof will now be described, by way of example only and not in any limitative sense, with reference to the accompanying drawings, in which:

Figures 1a to 1d show the formation of a solid filament of a first embodiment of the invention;

Figures 2a to 2d show the formation of a solid filament of a second embodiment of the invention;

Figures 3a to 3d show the formation of a solid filament of a third embodiment of the invention;

Figure 4 is a schematic representation of a spinneret

plate having a substantially swastika shaped cross-section used in the formation of the solid filament of Figures 3a to 3d;

Figure 5 is a schematic representation of an apparatus suitable for producing a solid filament according to the present invention;

Figure 6 is a schematic representation of a spinneret forming part of an apparatus suitable for producing a solid filament according to the present invention;

Figure 7 is a schematic representation of a portion of an apparatus suitable for producing a solid filament according to the present invention;

Figure 8 is a schematic representation of a complete production line suitable for producing solid filament according to the present invention.

Figure 9 is a schematic representation showing fibre resilience of solid filaments produced using apparatus according to the present invention compared to other known filaments; and

Figure 10 is a micrograph showing the solid cross section of filaments formed by means of the present invention.

Referring in detail to Figure 1a, a spinneret plate (not shown) has an array of C-shaped apertures drilled therein by any suitable means such as laser drilling, as will be appreciated by persons skilled in the art. At the exit face of the spinneret plate, each of the C-shaped apertures is surrounded by a generally circular groove of diameter similar to that of the C-shaped aperture.

As will be appreciated by persons skilled in the art, when the spinneret plate is in use, molten thermoplastic material such as polypropylene is forced through the apertures in the spinneret plate, and emerges therefrom downstream of the spinneret plate aided by suitable means such as rollers. In such a process, the thermoplastic material emerges in the direction of arrow A shown in Figures 1a to 1d, and the thermoplastic material forms a C-shaped tubular portion 1 on passing through the C-shaped aperture.

At this stage there is no molecular orientation within

the fibres.

Referring now to Figure 1b, as the still molten thermoplastic material passes into the generally circular groove surrounding the C-shaped aperture, the molten polymer floods into the groove and forms a closed toroidal portion 2 enclosing a central channel 3. As a result, external air cannot enter into the central channel 3 to support a hollow fibre.

Further downstream, as shown in Figure 1c, as the fibre 5 emerges from the spinneret plate, a conical void 4 forms inside the fibre. At this stage, the fibre 5 is cooled in a transverse direction as shown by arrow B by means of cooling air, or by passing the fibre 5 over a cooled roller. As a result, the upper portion of the fibre 5 is subjected to a greater degree of cooling than the lower portion. This effect is enhanced because the lower portion of the fibre 5 is insulated from the upper portion by the conical void 4 while the interior of the fibre 5 is still molten.

Subsequently, as shown in Figure 1d, the fibre collapses as a result of atmospheric pressure, and forms a solid fibre. It has been found that even when examined under a scanning microscope, no weld line is visible where the ends of the originally C-shaped portion shown in Figure 1a have joined together. In addition, as a result of the non-uniform transverse cooling of the fibre 5, it is found that the turbulence generated in the thermoplastic material passes from its glass transition phase to its crystallised phase at different rates for the top and bottom portions of the fibre, which produces a significant degree of helical crimp with high resiliency and modulus of elasticity.

Referring to Figures 2a to 2d, in which parts common to the embodiment of Figures 1a to 1d are denoted by like reference numerals but increased by 10, thermoplastic material travelling in the direction of arrow C shown in the Figure through a spinneret plate (not shown) having a plurality of S-shaped apertures, each of which is surrounded at the exit face of the spinneret plate by a groove in the shape of a figure 8.

As the thermoplastic material in the form of an S-shaped tube 11 passes into the figure 8 shaped groove, the molten polymer fills the groove to form a portion 12 in the form of a figure 8 enclosing two voids 13 as shown in Figure 2b.

As a result of two voids being formed inside the fibre 15, a pair of converging voids 14 is formed in the fibre as shown in Figure 2c and when the fibre 15 is subject to transverse cooling in the direction shown by arrow D, the lower part of the fibre 15 is subjected to even slower cooling compared to the upper portion than in the case of the embodiment of Figure 1.

Referring to Figures 3a to 3c, in which parts common to the embodiment of Figures 1a to 1d are denoted by like reference numerals but increased by 20, thermoplastic material travels in the direction of arrow E shown in the Figures through a spinneret plate shown in more detail in Figure 4 having a generally swastika shaped cross section, the arms of which are surrounded by a generally circular groove at the exit plate. As the thermoplastic material in the form of a tube having a generally swastika shaped cross section 21 passes into the circular groove, the molten polymer fills the groove to form the closed toroidal portion 22. This prevents air from entering the four tubes 24 created by the swastika shape of the spinneret plate. There are thus four voids 24 formed inside the fibre 25. These voids 24 are converging, and when the fibre 25 is subject to transverse cooling in a direction shown by arrow F, the voids collapse due to the external atmospheric air pressure. At this stage the polymer is still molten and as the sides of the voids touch they weld together to form a solid fibre 25.

The now solidified fibre is formed into an almost circular cross section or shaped fibre with no central voids. On stretching and releasing the tension in the fibres, the fibres intensely self crimp into helical crimped fibres.

Referring in detail to Figure 4, a spinneret plate 56 (Figure 6) has an array of swastika shaped apertures 40 of the type shown in Figure 3a drilled therein by any suitable means

such as laser drilling.

The spinneret has a polymer wetted area of 35.5mm width by 240mm long. The swastika shaped apertures are contained within a diameter of 1.350mm. Angle a in Figure 4 is 22.82°, and the width of the tube defined by the swastika shaped aperture is 0.15mm.

On the exit face of each swastika shaped orifice a circular groove is cut also having a diameter of 1.35mm. The depth of the groove is 0.25mm. This means that polymer exiting from each orifice flows into the groove to form enclosed toroidal portion thus preventing air from being drawn into the four central voids 25.

Referring now to Figures 5, 6, 7 and 8 the spinneret described hereinabove with reference to Figure 3 is fitted to an extrusion head of a standard fibre extrusion line 50 (shown in more detail in Figure 8) which is arranged to extrude the fibres horizontally. Initial cooling of the fibres is effected by a strong blast of cooling air at a temperature of 14°C blown through a slot cooling duct 60 positioned in the space between the spinneret 56 and cooling tube 52 and from the upper side of the fibre array. This creates a temperature differential across the diameter of the fibre, since on side of the fibres is nearer to the duct. Positioned immediately in front of the spinneret is a section of a non rotating thin walled circular cooling tube 52 of 180mm diameter in which cooled water having a temperature of 5°C is circulated. The freshly formed fibres 54 having been initially cooled by a blast of air now pass around one third of the circumference of this cooling tube 52. The contact point of the fibres on the cooling tube is 110mm from the face of the spinneret 56. Preferably, the tube is so arranged that the side of the fibre which was nearest to the duct is the side of the fibre in contact with the cooling tube.

The solidified fibres are then passed over a spin finish application roller 81 in order to coat the fibre with an anti-static solution to aid further processing of the fibre without undue generation of static electricity in the fibres.

The fibres are then passed through a heated oven 82, or

contact heated rollers in order that the fibres are heated without subjecting them to any undue tension and without creating any molecular orientation in the fibres.

The heat treated but unstretched fibres are then brought together as a tow of fibres by means of condenser rollers 53 prior to entering the staple fibre stretching godets 84, 85.

Example

An extruder 86 which fed the spinneret 56 with molten polymer was charged with a batch of 8 MFI (melt flow index) Polypropylene Homopolymer resin of narrow molecular weight distribution made by Montell and sold as type PLZ987.

The extruder barrel was heated to a temperature profile of 200°C to 220°C and the head and spinneret maintained at 210°C. The extruder was adjusted so that the extruded fibres after stretching with a stretch ratio of 3:1 and after heat setting had a denier of 12 per fibre. The speed of godet set No 1 was 25 metres per minute and godet set No 2 was 75 meters per minute.

Situated between godet No 1 and godet No 2 was a hot air oven with steam injection 87 whose temperature was maintained at 100°C. The fibres prior to stretching were heated to a temperature of 120°C by passing them through the hot air oven 82.

The stretched fibres of this experiment were cut to a length of 150mm and then heat set at a temperature of 130°C for a period of 3 minutes in a heat setting oven. During heat setting the fibres shrank in length by 14% but took on a very pronounced helical crimp which could not be removed even under very high fibre tension. The degree of crimping of the relaxed heat set fibres was measured as 75 Crimp Percent which was determined by the formula:-

$$\frac{\text{Original Length of Nonheat Set Fibre} - \text{Length of Fibre after Heat Setting}}{\text{Original Length of Nonheat Set Fibre}} \times 100$$

The fibres produced were examined by hand and found to have a very high resiliency, bulk and a very soft feel when compared to normal 12 denier Polypropylene fibres made by the normal short spin route for Polypropylene Fibres and crimped by a stuffer box crimper.

A device for measuring the Resiliency of Loose Staple Fibre is the WRONZ Loose Wool Bulkometer, developed and manufactured by Wronz Developments Ltd., Private Bag 4749 Christchurch, New Zealand.

A 10 grams sample of the Polypropylene fibre produced was tested along with 10 grams of normal 12 denier Polypropylene Fibre and 10 grams of Southdown wool Fleece in a Wronz Bulkometer, the results are shown in Figure 9.

Referring to Figure 10, fibres formed according to Figures 3a to 3d are shown. The Figure is in the form of a printout of a photo micrograph of a cross section of 12 denier Polypropylene Fibre made according to Figures 3a to 3d. The magnification of a single fibre is approximately times 820 and shows that there is no sign of internal voids in any of the fibres.

It will be appreciated by persons skilled in the art that the above embodiments have been described by way of example only and not in any limitative sense and that various alterations and modifications are possible without departure from the scope of the invention as defined by the appended claims. In particular, a number of different cross sections of spinneret aperture can be used. For example, a swastika shape aperture causes the fibre to weld together with four voids enclosed therein, which even further enhances the non-uniform cooling effect of the fibre.

CLAIMS:

1. A spinneret plate for use in producing crimped solid thermoplastic filaments, the spinneret plate comprising a plurality of apertures therethrough, wherein each said aperture comprises:

a first portion having a first transverse cross section defining a discontinuous loop, wherein the loop substantially surrounds a solid portion of the spinneret plate; and

a second portion having a second transverse cross section defining a continuous loop corresponding substantially to the discontinuous loop of said first portion,

wherein molten thermoplastic material is passed in use through the apertures in a direction from the first portions to the second portions.

2. A spinneret plate according to claim 1, wherein each said first portion has a substantially C-shaped cross section.

3. A spinneret plate according to claim 1, wherein each said first portion has a substantially S-shaped cross section.

4. A spinneret plate according to claim 1, wherein each said first portion has a substantially swastika-shaped cross section.

5. An apparatus for producing crimped solid thermoplastic filaments, the apparatus comprising:

feeding means for feeding molten thermoplastic material to a spinneret plate according to any one of the preceding claims so as to pass through said apertures in a direction from said first portion to said second portions, thereby forming fibres; and

cooling means for non-uniform cooling of the fibres in a direction transverse to the drawing direction.

6 . An apparatus according to claim 5, wherein said cooling means comprises air blower means for blowing air onto the filament from one side thereof.

7. A method of producing crimped solid thermoplastic filaments, the method comprising: passing molten thermoplastic material through a spinneret plate to form filaments according to any one of claims 1 to 4; cooling said filaments in a non-uniform manner in a direction transverse to the drawing direction.

8. A method according to claim 9, wherein the method is a method for producing polypropylene fibres.

9. A spinneret plate for use in producing crimped solid thermoplastic filaments, the spinneret plate substantially as hereinbefore described with reference to the accompanying drawings.

10. An apparatus for producing crimped solid thermoplastic filaments, the apparatus substantially as hereinbefore described with reference to the accompanying drawings.

11. A method of producing crimped solid thermoplastic filaments, the method substantially as hereinbefore described with reference to the accompanying drawings.

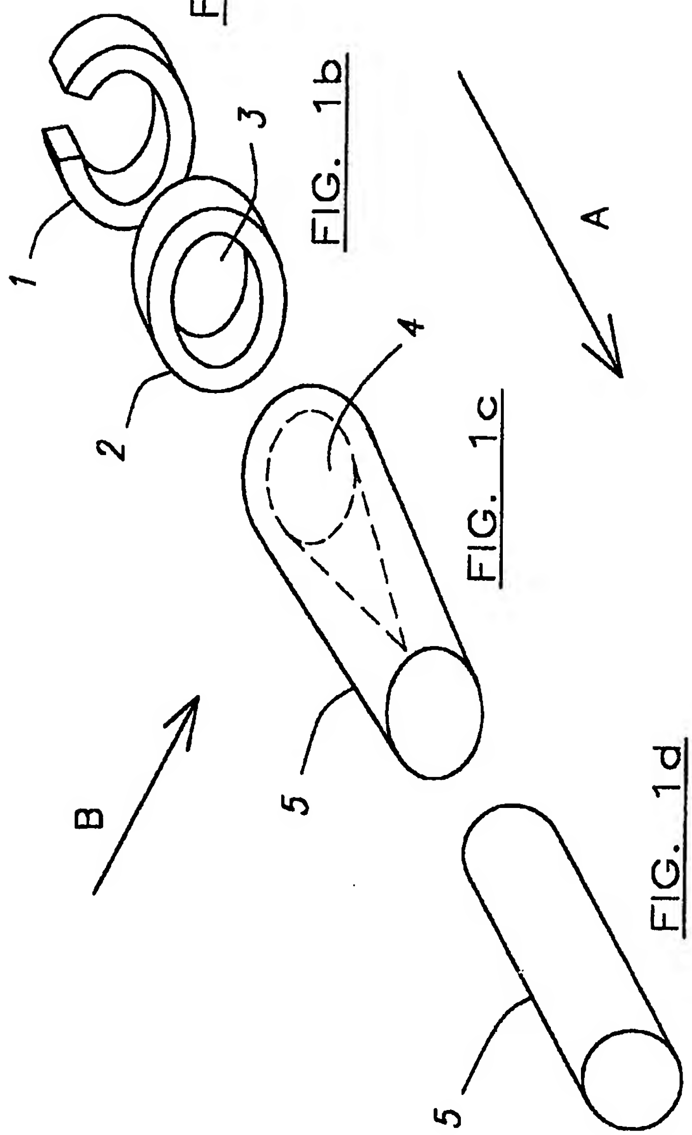


FIG. 1a

FIG. 1b

FIG. 1c

FIG. 1d

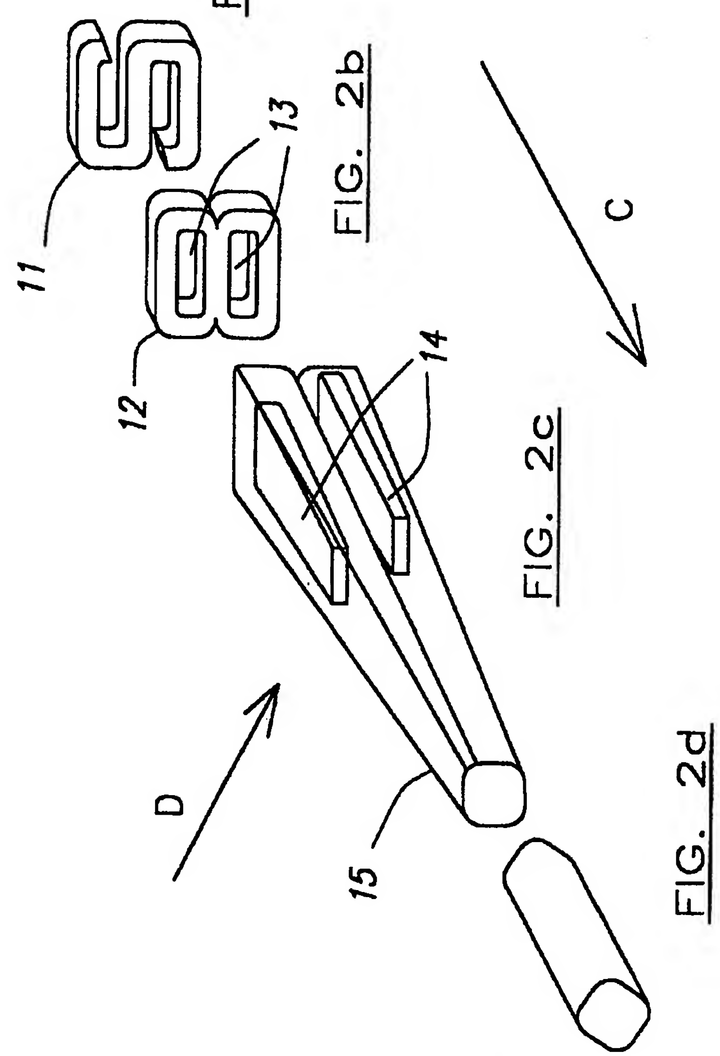


FIG. 2a

FIG. 2b

FIG. 2c

FIG. 2d

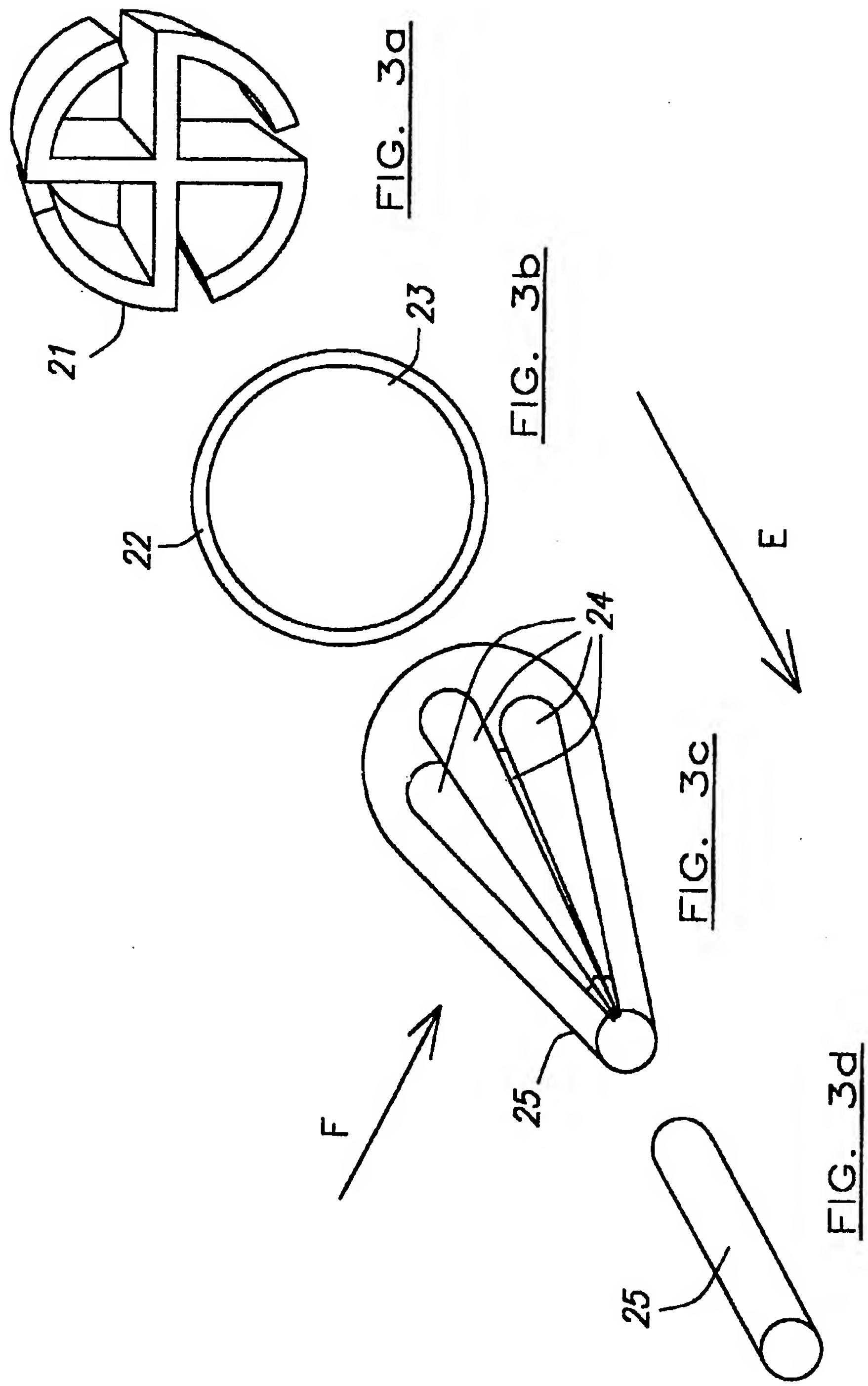
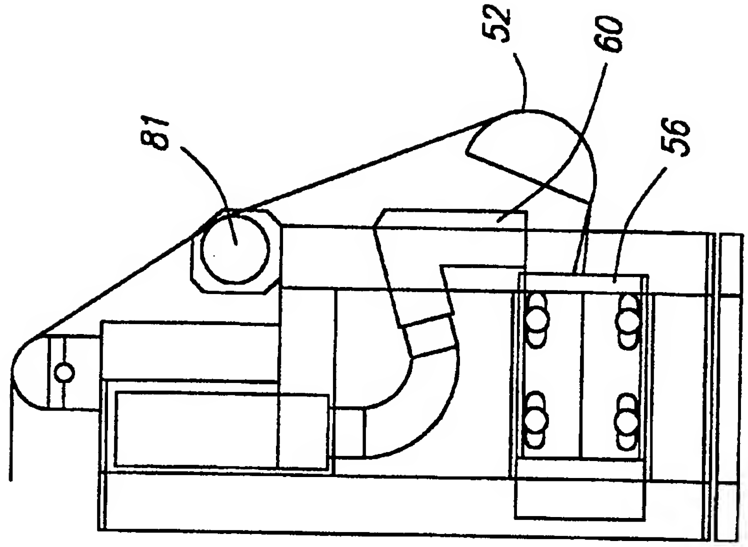


FIG. 3a

FIG. 3b

FIG. 3c

FIG. 3d



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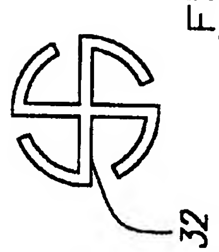

FIG. 4

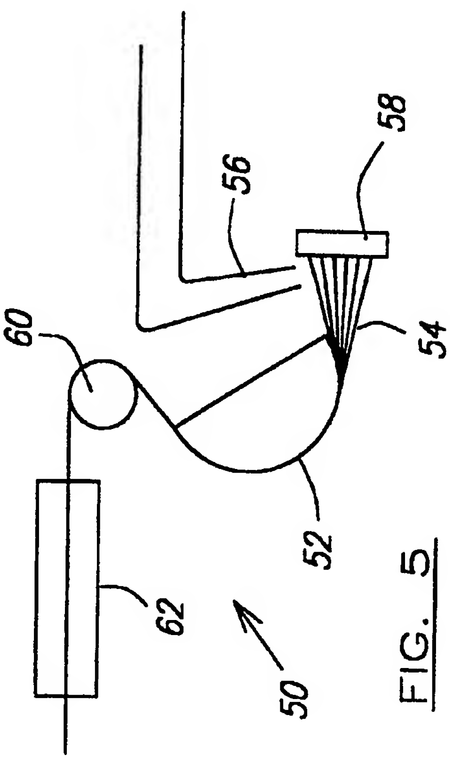

FIG. 5

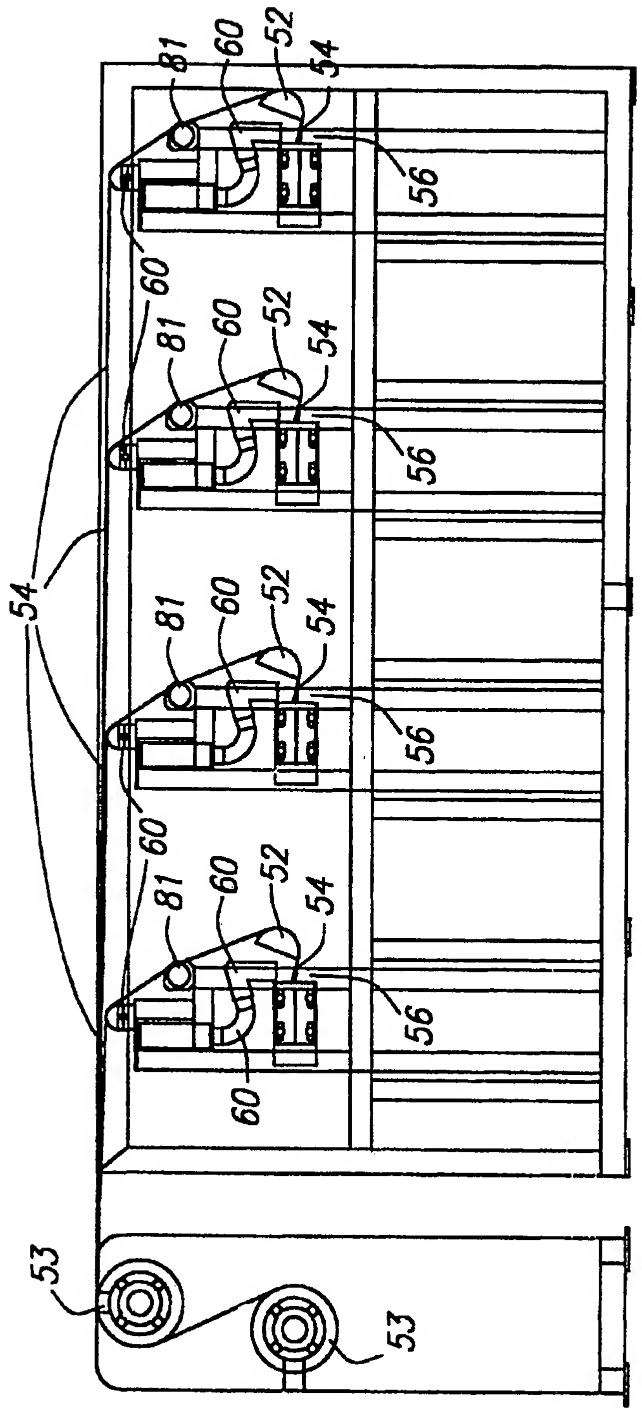
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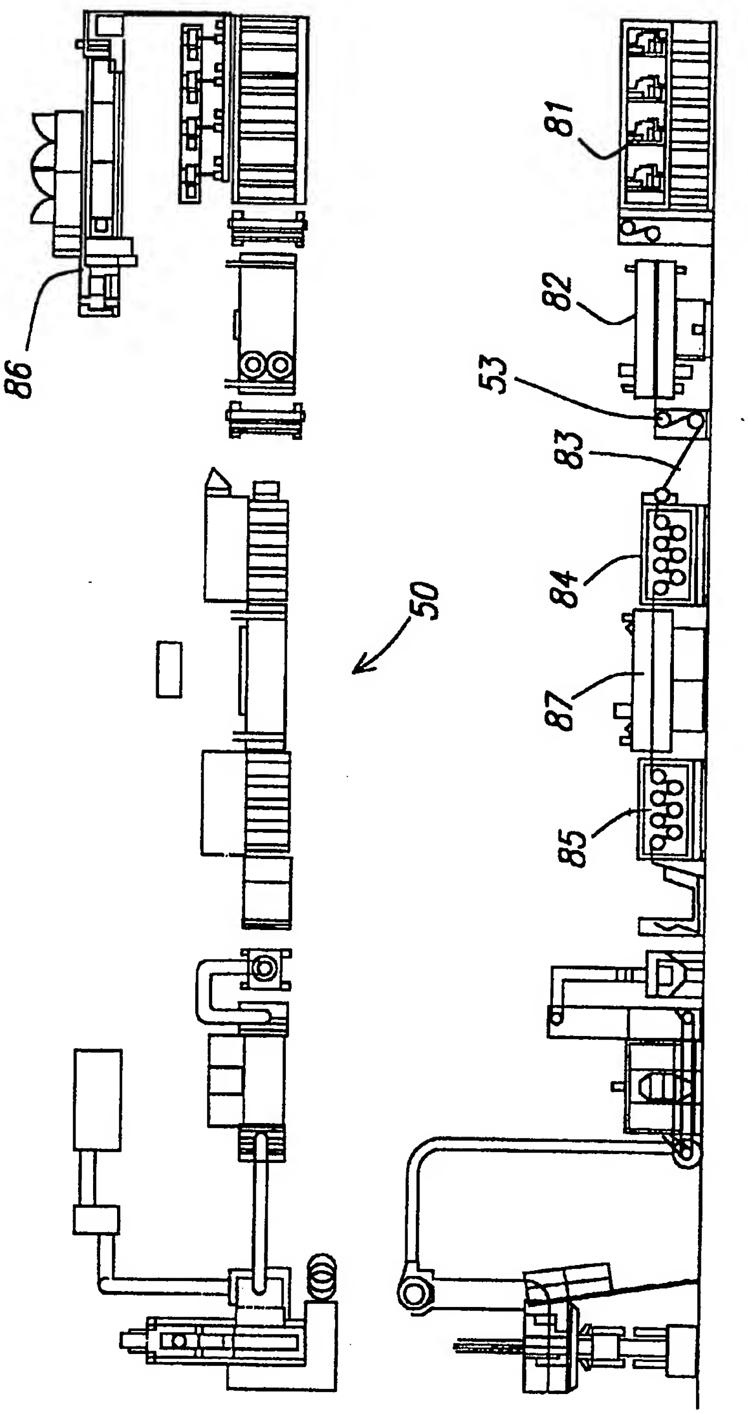
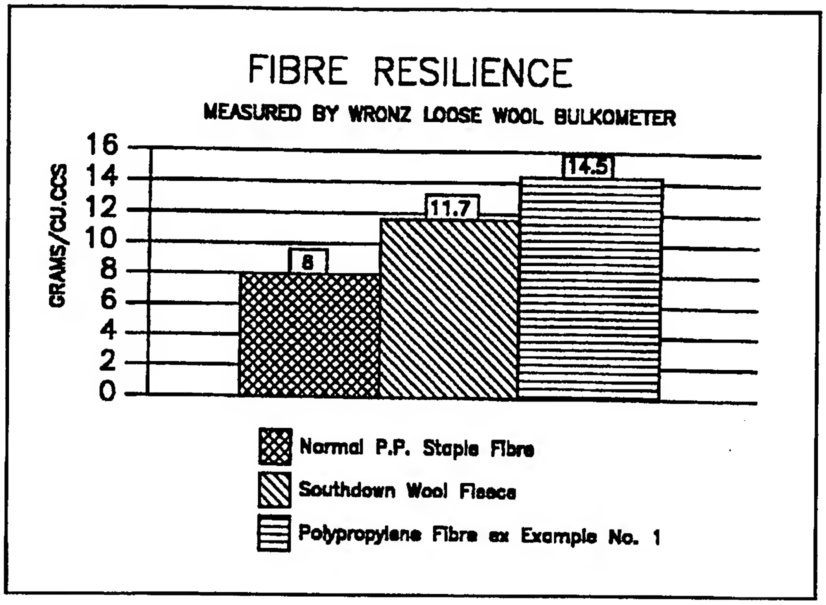
FIG. 7

FIG. 8

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Normal P.P. Staple Fibre
Southdown Wool Fleece
Polypropylene Fibre ex Example No. 1

FIG. 9

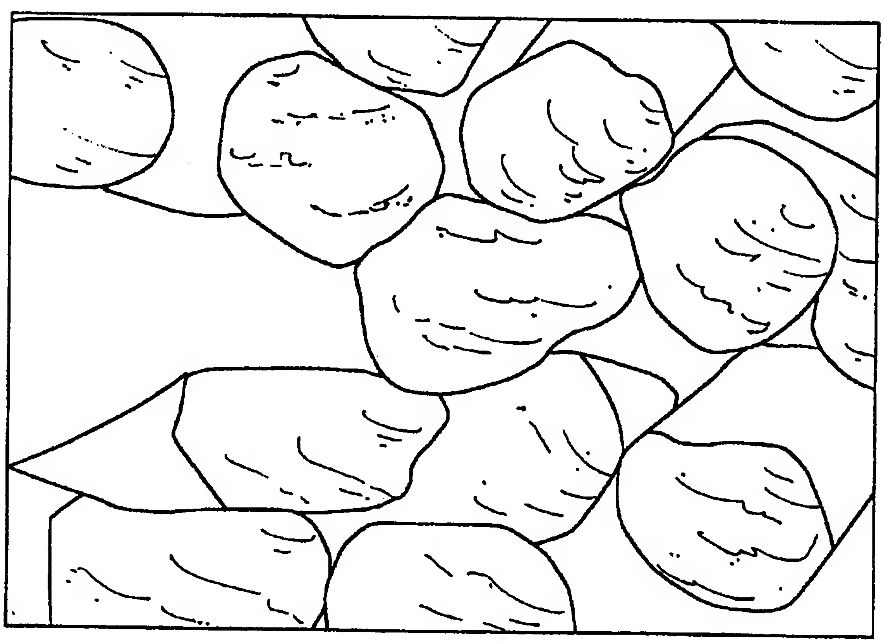

FIG. 10

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 98/00987

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 D01D4/02 D01D5/088 D01D5/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 D01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 28 11 794 A (MONSANTO CO) 21 September 1978 see page 8, line 9 - line 13; claims 1,9; figures 2,3 ---	1-6,9,10
X	GB 936 729 A (E. I. DU PONT DE NEMOURS AND COMPANY) 11 September 1963 see page 2, line 61 - line 89 see page 3, line 96 - line 109; figure 1; example 11 ---	7,8,11
A	PATENT ABSTRACTS OF JAPAN vol. 006, no. 131 (C-114), 17 July 1982 & JP 57 056512 A (NIPPON ESTER CO LTD), 5 April 1982, see abstract -----	1-6,9,10

☐ Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search	Date of mailing of the international search report
7 August 1998	17/08/1998

Name and mailing address of the ISA	Authorized officer
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